MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 2, 2016/2017

EEE2146 – MICROELECTRONIC CIRCUIT ANALYSIS AND DESIGN
(All sections / Groups)

4 MARCH 2017
9.00 a.m – 11.00 a.m
(2 Hours)

INSTRUCTIONS TO STUDENTS

1. This examination paper consists of 6 pages with 4 questions only.
2. Attempt **ALL FOUR** questions. All questions carry equal marks and the distribution of the marks for each question is given.
3. Please print all your answers in the Answer Booklet provided.

Question 1

(a) Compute the transistor base current, I_B, emitter current, I_E, emitter voltage, V_E and base voltage, V_B (with respect to ground) of the circuit shown in Figure Q1. Given that $V_{CC} = 9$ V and the transistor $V_{BE(active)} = 0.7$ V, current gain $\beta = 100$ and early voltage $V_A = \infty$. [7 marks]

(b) Draw the small-signal equivalent circuit of the amplifier circuit in Figure Q1 using the simplified hybrid model. [5 marks]

(c) From the small-signal equivalent circuit, determine the small signal input resistance, R_{IN} and the overall voltage gain. $\frac{v_o}{v_s}$. Given that voltage equivalence of temperature $V_T = 26$ mV.

[13 marks]

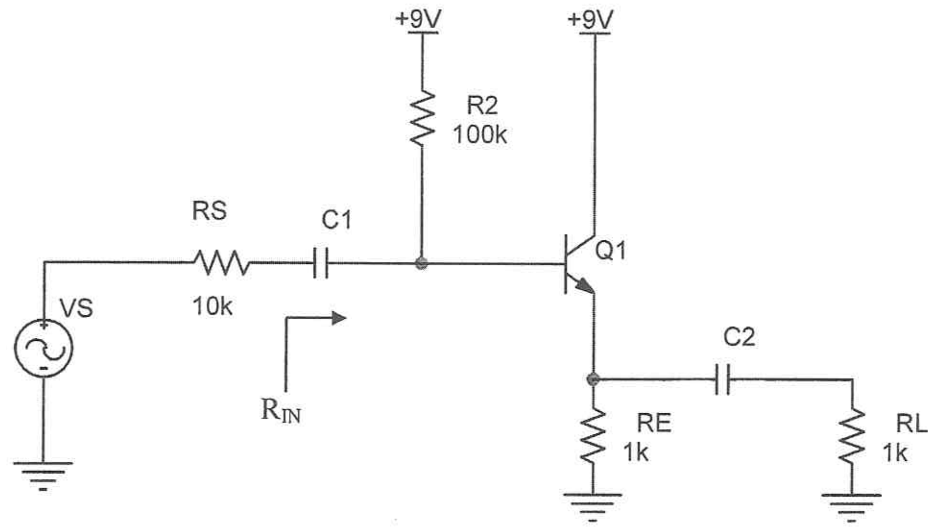

Figure Q1

Continued...

Question 2

The circuit shown in Figure Q2 is a common-source amplifier. The transistor has V_t = 1.5V, $k'_n(W/L)$ = 0.25 mA/V^2 and V_A = 50 V.

(a) From the DC analysis, compute the values for DC drain current, I_D and DC drain voltage, V_D. Assume the DC gate current, I_G = 0.

[7 marks]

(b) Draw a small-signal equivalent circuit for the circuit shown in Figure Q2 using the simplified hybrid model.

[5 marks]

(c) Derive and compute the small-signal voltage gain, $\frac{v_O}{v_i}$, then compute the input resistance R_{IN}.

[13 marks]

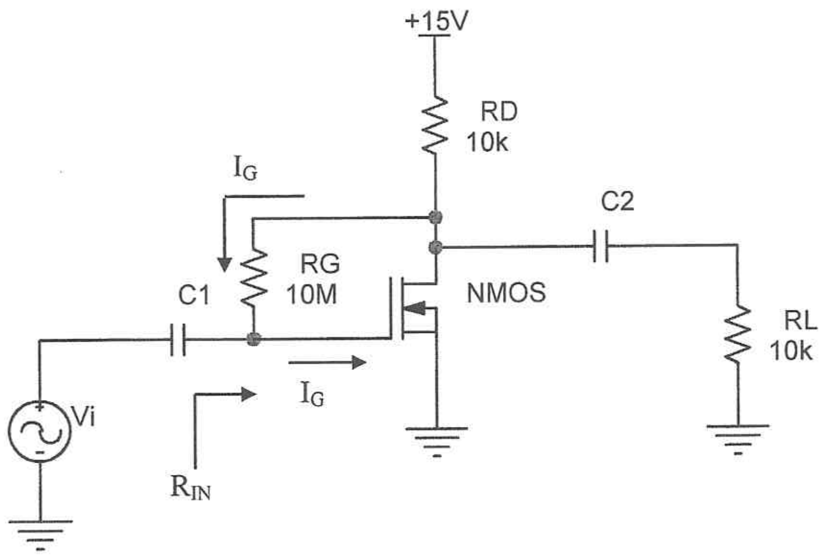

Figure Q2

Question 3

Figure Q3 below shows a MOSFET current mirror and a MOSFET differential amplifier. The voltage supply $V_{DD} = V_{SS} = 1.5V$. Assume that all transistors are identical (same k_n' and V_t) and the transistors are in saturation.

(a) Find I_{REF} if $V_{GS4} = V_{GS3} = 1$ V and $R_1 = 2.5$ kΩ. Then, compute I_q when $(W/L)_4 = 2$, $(W/L)_3 = 4$, $k_n' = 200\mu$ A/V^2 and $V_t = 0.5$ V. [6 marks]

(b) Draw the differential-mode small signal equivalent circuit for the differential amplifier below, then prove that the differential-mode voltage gain,

$$A_d = \frac{v_{od}}{v_{id}} = -g_m\left(R_D \| r_o\right).$$

[9 marks]

(c) Then, compute the values of R_{D1} and R_{D2}. Assume M1 and M2 are identical with $V_{OV} = 0.5$, early voltage, $V_A = \infty$ and the differential-mode voltage gain, $A_d = -250$.

[10 marks]

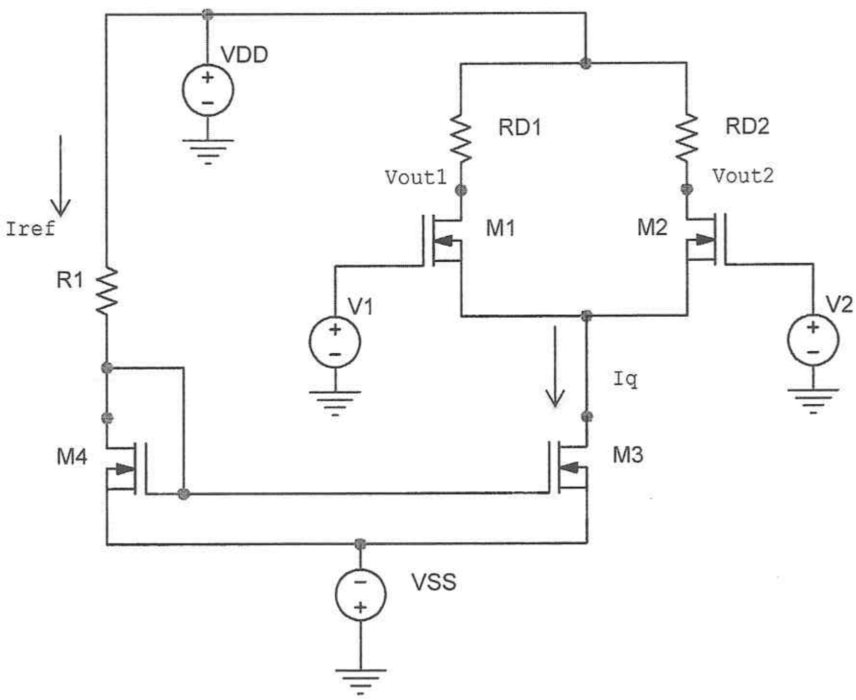

Figure Q3

Question 4

(a) Draw a low frequency small signal equivalent circuit of the circuit shown in Figure Q4 (a) using hybrid-π model. Ignore the effect of the transistor output resistance, r_o. Then, derive the equations for the lower cutoff frequencies f_{C1} and f_{C2} of the circuits. Use necessary equivalent circuits to show in your derivations.

[11 marks]

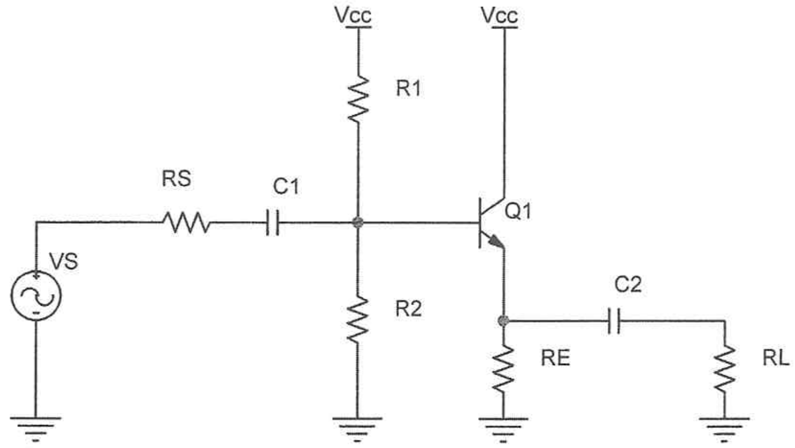

Figure Q4(a)

(b) The non-inverting amplifier shown in Figure Q4 (b) is a series-series feedback transconductance amplifier. Derive the equations for gain A_f, output resistance R_{of} and input resistance R_{if}. Draw the amplifier equivalent circuit to assist the derivations.

[14 marks]

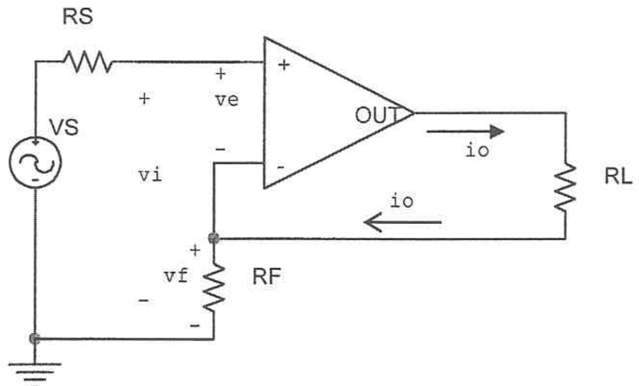

Figure Q4(b)

Appendix: Useful formula

$$V_T = \frac{kT}{q} \approx 26\text{mV}$$

$$I_B = \frac{I_C}{\beta_F}$$

$$I_E = \frac{-I_C}{\alpha_F}$$

$$I_C = I_S\left(\exp\left(\frac{V_{BE}}{V_T}\right) - 1\right)\left(1 + \frac{V_{CE}}{V_A}\right)$$

$$g_m = \frac{\partial I_C}{\partial V_{BE}} = \frac{I_C}{V_T}$$

$$C_b = \tau_F g_m$$

$$r_\pi = \frac{\beta}{g_m} = \frac{\beta V_T}{I_C} = \frac{V_T}{I_B}$$

$$g_m v_\pi = \beta i_b$$

$$r_o = 1 \Big/ \frac{\partial I_C}{\partial V_{CE}} = \frac{V_A}{I_C}$$

$$r_\mu = \beta r_o$$

$$V_{DS} < V_{GS} - V_t;$$

$$I_D = k'\left(\frac{W}{L}\right)\left[(V_{GS} - V_t)V_{DS} - \frac{1}{2}V_{DS}^2\right]$$

$$r_{ds} = \frac{V_{DS}}{i_D}$$

$$V_{DS} > V_{GS} - V_t;$$

$$I_D = \frac{k'}{2}\left(\frac{W}{L}\right)(V_{GS} - V_t)^2$$

$$V_{DS} > V_{DS(SAT)};$$

$$I_D = \frac{k'}{2}\left(\frac{W}{L}\right)(V_{GS} - V_t)^2(1 + \lambda V_{DS})$$

$$V_A = V_M = L_{eff}\left(\frac{dX_d}{dV_{DS}}\right)^{-1} = \frac{1}{\lambda}$$

$$r_o = \frac{V_A}{I_D}$$

$$\phi_f = \frac{kT}{q}\ln\left(\frac{N_A}{n_i}\right)$$

$$\gamma = \frac{\sqrt{2q\varepsilon N_A}}{C_{ox}}$$

$$V_t = V_{to} + \gamma\left(\sqrt{2\phi_f + V_{SB}} - \sqrt{2\phi_f}\right)$$

$$C_{ox} = \frac{\varepsilon_{ox}}{t_{ox}}$$

$$k' = \mu_n C_{ox}$$

$$V_{OV} = V_{GS} - V_t$$

$$g_m = \frac{\partial I_D}{\partial V_{GS}} = k'\frac{W}{L}V_{OV} = \frac{2I_D}{V_{OV}}$$

$$C_{gs} = C_{gd} = \frac{C_{ox}WL}{2}$$

$$g_{mb} = \frac{\partial I_D}{\partial V_{BS}}$$

$$\frac{\partial V_t}{\partial V_{BS}} = \frac{-\gamma}{2\sqrt{2\phi_f + V_{SB}}} = -\chi$$

$$\chi = \frac{C_{js}}{C_{ox}} = \frac{g_{mb}}{g_m}$$

$$f_T = \frac{1.5\mu_n}{2\pi L^2}V_{OV}$$

$$f_T = \frac{2\mu_n}{2\pi W_B^2}V_T$$

$$I_D = I_t\frac{W}{L}\exp\left(\frac{V_{OV}}{nV_T}\right)\left[1 - \exp\left(\frac{-V_{DS}}{V_T}\right)\right]$$

End of Paper